OXYGENATED GASOLINE-THE CALIFORNIA EXPERIENCE

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ABSTRACT

The Air Resources Board (ARB) adopted regulations in December 1991, which require that gasoline contain 1.8 to 2.2 weight percent oxygen during specified months. The regulations were adopted in response to the Federal Clean Air Act Amendments of 1990. California's wintertime oxygenates program was implemented November 1, 1992. The use of oxygenated gasoline reduced ambient carbon monoxide concentrations by six to ten percent during the first implementation season. The wintertime oxygenates regulations sunset February 29, 1996. At that time, the wintertime oxygen content requirement becomes part of the Phase 2 reformulated gasoline regulations.

INTRODUCTION

This paper summarizes the California wintertime oxygenates regulations and discusses California's experience in implementing these regulations.

In response to the requirements of the federal Clean Air Act Amendments of 1990 (Act), the ARB adopted regulations in December 1991, which require that gasoline contain 1.8 to 2.2 weight percent oxygen during specified months. These regulations were implemented on November 1, 1992. Because California's regulations differ from the federal requirements, the ARB requested a partial waiver under section 211(m)(3) of the Act. The U.S. Environmental Protection Agency (U.S.EPA) is currently reviewing ARB's request for a waiver.

Based on our review of the program's first implementation season, the Board approved minor modifications to the regulations on September 9, 1993, which are intended to provide additional flexibility to those required to comply with the regulations, while not compromising the overall effectiveness of the program.

BACKGROUND

The Federal Requirements

The Act requires states with carbon monoxide (CO) nonattainment areas to implement oxygenated gasoline programs in these areas. In most cases, the states' programs must require that gasoline sold in the nonattainment areas have an oxygen content of at least 2.7 weight percent, during the specified months. The states are required to submit their oxygenated gasoline regulations as a revision to the State Implementation Plan (SIP). The U.S.EPA identified eight areas in California in which an oxygenated gasoline program is required, including: the Chico Metropolitan Statistical Area (MSA), the Sacramento MSA, the San Diego MSA, the Modesto MSA, the Fresno MSA, the Stockton MSA, the San Francisco-Oakland-San Jose Consolidated Metropolitan Statistical Area (CMSA), and the Los Angeles-Anaheim-Riverside CMSA. The EPA also specified the control period applicable in each of the affected areas[1]. The control periods are listed in Table 1.

ARB's Actions to Comply with the Act

In response to the requirements of section 211(m), the ARB promulgated oxygenated gasoline regulations following a hearing on December 12, 1991. The regulations were submitted as a revision to the SIP in October 1992. The wintertime oxygenates regulations sunset February 29, 1996, after which the year-round oxygen content requirements in the ARB's Phase 2 reformulated gasoline regulations will go into effect. Because over 70 percent of the gasoline used statewide is consumed in the U.S.EPA-designated areas, the Board made the wintertime oxygenates regulations applicable statewide. Additionally, the Board concluded that a statewide program simplifies enforcement and maximizes the CO emission reductions achieved in the nonattainment areas.

In setting the standards, the Board determined that while requiring the 2.7 weight percent oxygen content mandated by the Act would result in greater CO reductions it would also result in increased emissions of NO_x. An increase in NO_x emissions would interfere with efforts to attain the ambient air quality standards for particulate matter (PM_{10}), nitrogen dioxide (NO_2) and ozone. Therefore, the Board established a minimum and maximum oxygen content requirement at 1.8 and 2.2 weight percent, respectively.

The Board has requested that the U.S.EPA partially waive the minimum oxygen content requirement of 2.7 weight percent specified in the Act. Section 211(m)(3)(A) of the Act directs the U.S.EPA to waive the requirement for any area where the state demonstrates that the use of oxygenated gasoline would prevent or interfere with the area's attainment of an ambient air quality standard for any pollutant other than CO.

IMPACT OF OXYGENATED GASOLINE ON MOTOR VEHICLE EMISSIONS

Adding oxygen to gasoline affects the properties of gasoline in both performance and emissions. Generally, the oxygenates used today are ethanol and methyl tertiary butyl ether (MTBE). Over the past several years, there have been a number of test programs conducted to evaluate the impact of oxygen content on emissions. In the process of developing the wintertime oxygenates regulations, we evaluated all of the studies available to us at

the time and concluded that oxygen content in gasoline greater than 2.2 weight percent would increase NO_x emissions from motor vehicles[2,3,4]. In general, NO_x emissions increase as oxygen content increases.

Since the adoption of the wintertime oxygenates regulations and the Phase 2 reformulated gasoline regulations, we have been working to develop a predictive model to estimate emissions from alternative gasoline formulations that might be used in the vehicle fleet. As part of our waiver request to U.S.EPA, we used a draft version of the predictive model to evaluate the emissions characteristics of the most likely gasoline formulation that would be produced under the federal program[4]. This gasoline formualtion was developed as part of an analysis conducted by Turner Mason and Company for the Western States Petroleum Association. It should be noted that variations in the gasoline formulations actually produced will influence the actual impact on NO_x emissions. **Figure 1** shows the estimated impact on NO_x emissions for the different vehicle technology groups.

RATIONAL FOR LIMITING THE OXYGEN CONTENT OF GASOLINE

Emissions Inventory

Motor vehicle emissions are a major source of pollutant emissions, including CO, hydrocarbons (HC), and NO_x. HC and NO_x are precursors to ozone and PM_{10}. **Figure 2** shows that in 1987 emissions from on-road gasoline motor vehicles constituted about 57 percent of the total CO inventory, 35 percent of the VOC inventory, and 38 percent of the NO_x inventory. Gasoline vehicles accounted for about 36 percent of the PM_{10} precursors.

Air Quality in EPA-designated Areas

Both the ozone and PM_{10} standards are exceeded in all EPA-designated areas during some time in the control period. **Figure 3** shows the average number of days the state ozone standard was exceeded during the period of 1987 through 1990 for five air basins (which contain all of the U.S.EPA designated areas). **Figure 4** shows the average percent of PM_{10} observations exceeding the state standard. Because violations of the standards for CO, NO_2, ozone, and PM_{10} can occur simultaneously, it is critical that the efforts to reduce CO emissions don't increase emissions of the other pollutants.

As noted earlier, use of gasoline with oxygen content greater than 2.2 weight percent would result in larger CO reductions of CO emissions, but it would also increase NO_x emissions. Thus, it is critical to balance the need for CO reductions and the need to avoid NO_x increases. California's oxygenated gasoline regulations were designed to balance these competing effects.

ARB'S EXPERIENCE IMPLEMENTING THE OXYGENATED GASOLINE PROGRAM

Implementation Issues

During the first implementation period of the wintertime oxygenated gasoline program, staff became aware of various concerns regarding the application of the wintertime oxygenates regulations. After evaluation of the program, staff proposed several minor modifications to the regulations which were adopted by the Board on September 9, 1993[5]. The modifications include changing the control period applicable in the San Luis Obispo County, allowing the distribution of gasoline containing greater than 2.2 weight percent oxygen during the transition period, providing a one pound per square inch Reid vapor pressure exemption for ethanol blended gasoline produced during the calibration of blending equipment, and providing an exemption for small gasoline retailers that obtain their gasoline from areas outside California, if they meet specified conditions. These changes are intended to provide industry with additional flexibility in complying with the regulations, while maintaining the effectiveness of the regulations.

Air Quality Improvements During the 1992/93 Winter

Results of an analysis of CO, NO_x, and HC ambient air quality data collected at nine monitoring stations during the November 15, 1992 through Januarry 31, 1993 period indicates that concentrations of CO were significantly lower than past winters[6]. Although the 1992/93 winter had very favorable meteorology, we believe some of the reduction in CO concentrations are due to the use of oxygenated gasoline.

A linear regression analysis was done on the available data for the winter periods of 1985/86 through 1991/92 to characterize trends for the three periods 6 to 9 a.m., 6 to 9 p.m., and daily mean concentrations. The regression equations were used to compute the expected concentrations for CO, NO_x, and HC for the 1992/93 winter. The actual values for 1992/93 winter were divided by the expected values derived from the regression analysis.

The ratio of the 1992/93 actual concentrations to the expected concentrations were 72 percent for CO and 78 percent for NOx, respectively. The ratios of the NO_x concentrations were assumed to characterized the atmospheric dispersion during the winter 1992/93. Thus, the difference between the CO ratios and the NO_x ratios was attributed to the use of the oxygenated gasoline. The analysis indicates that the use of oxygenated gasoline accounted for about a six to 10 percent reduction in CO concentrations. **Figure 5** shows a summary of the ratios of actual to expected the concentrations of CO and NO_x.

CONCLUSIONS

California has successfully implemented its oxygenated gasoline regulations applicable in the winter months which has resulted in significant reductions of carbon monoxide emissions from motor vehicles. Although the regulations require a lower oxygen content than the minimum 2.7 weight percent specified in the Act, the regulations have been effective in reducing CO emissions. Minor modifications were made in September 1993 to address concerns raised during the first implementation season.

California's wintertime oxygenates regulations will help bring all CO nonattainment areas into compliance with the CO ambient air quality standards by the statutorily require deadlines. Additionally, the Phase 2 reformulated gasoline regulations which will become effective in March of 1996, will result in an additional CO reduction of about five percent.

REFERENCES

1. U.S. Environmental Protection Agency, *Supplemental Notice of Proposed Guidance on Establishment of Control Periods Under Section 211(m) of the Clean Air Act as Amended*, 57, FR 4408, February 5, 1992.

2. Air Resources Board, *California Phase 2 Reformulated Gasoline Specifications, Volume 2 Proposed Regulation for California Wintertime Oxygenates Program*, October 4, 1991.

3. Air Resources Board, *California Wintertime Oxygenates Program, Technical Support Document, Request for a Waiver of the Minimum Oxygen Content Requirements for Wintertime Gasoline, Pursuant to Federal Clean Air Act Section 211(m)(3)(A)*, October 1992.

4. Air Resources Board, *California Wintertime Oxygenates Program, Technical Support Document, Request for a Waiver of the Minimum Oxygen Content Requirements for Wintertime Gasoline, Pursuant to Federal Clean Air Act Section 211(m)(3)(A)*, Supplemental Submittal to U.S. EPA Docket No. A-93-13, June 17, 1993.

5. Air Resources Board, *Proposed Amendments to Regulations Regarding the Oxygen Content of Gasoline, and Regarding Exemptions from Motor Vehicle Fuels Requirements for Fuels Used in Test Programs*, July 23, 1993.

6. Dolislager, Leon J., Air Resources Board, *Did the Wintertime Oxygenated Fuels Program Reduce Carbon Monoxide Concentration in California?*, Presented at the Tenth International Symposium on Alcohol Fuels, November 7-10, 1993, Colorado Springs, CO.

Table 1		
EPA-Designated Areas	Control Period	
Chico MSA*	October 1	January 31
Sacramento MSA	October 1	January 31
San Diego MSA	November 1	February 29
Modesto MSA	October 1	January 31
Fresno MSA	October 1	January 31
Stockton MSA	October 1	January 31
San Francisco-Oakland-San Jose CMSA**	October 1	January 31
Los Angeles-Anaheim-Riverside CMSA	October 1	February 29

* Metropolitan statistical area

** Consolidated metropolitan statistical area

Figure 1

Results of ARB's Predictive Model for Gasoline Most Likely to be Produced Under 2.7 wt. % Program

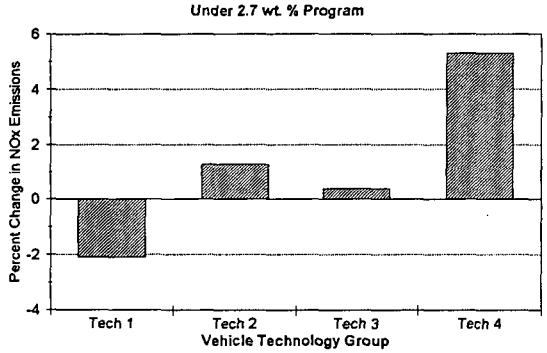

Figure 2

1987 Statewide Emissions Inventory

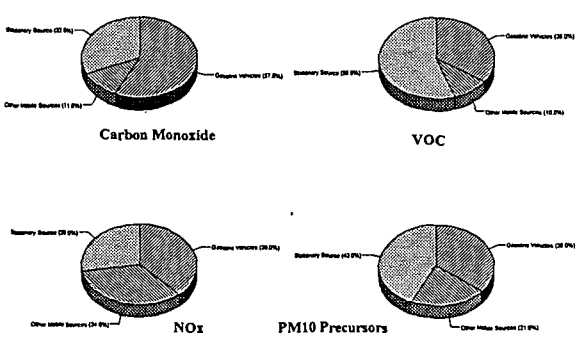

Figure 3

Avg. Number of Days Exceeding the *Ozone* State Standard

(1987 -1990 Data)

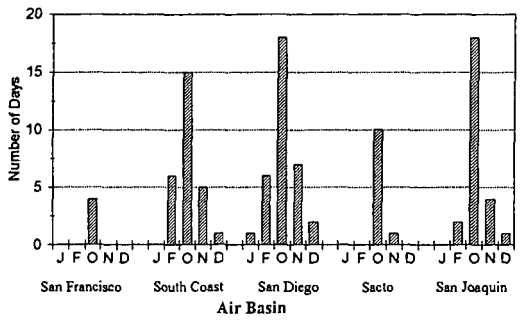

Figure 4

Avg. Percent of PM10 Observations Exceeding the 24-hr State Standard

(1987 - 1990 Data)

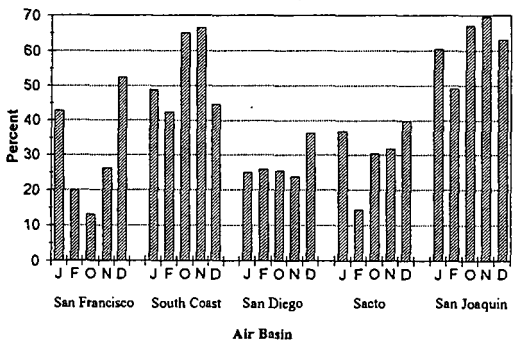

Figure 5

Ratios of Actual to Expected Concentrations

(winter 92/93)